Application Prospect Analysis of the Surface Water Source Heat-Pump in China[1]

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Abstract: Surface water resources in China are rather abundant and it can be use as the heat or cool source for heat pump. The winter surface water temperatures of 17 typical cities are investigated in December, and they are all distributed in the interval of 2~5℃. The critical technical issue in the surface water heat pump is how to extract the freezing latent heat. The urban surface water supplying areas of 102 large or median cities in China are measured and counted. The supply area ratio, and mean heating or cooling need index are calculated separately and the 102 cities are classified by the three parameters. The data indicate that surface water can supply heat and cool source for 42.1% of the urban waterside buildings in China.

Key words: surface water; heat pump; freezing latent heat; application prospect

1. INTRODUCTION

Heat-pump technology has got more and more recognition and applications in building heating and air conditioning, but the engineering application of the heat-pump system needs low-order heat and cool source [1,2]. Comparing with other heat and cool source, such as the air, earth, underground water, surface water has particular advantage: the flux of the water or capacity is larger, the heat exchange coefficient is bigger, the efficiency of the system is higher, the recharge well isn't needed, the investment is smaller, and the environment destruction is lighter and so on [3,4]. The surface water source in China is very abundant, except of the famous seven large drainage area (They are Changjiang River basin, Yellow River basin, Songhuajiang River basin, Huaihe River basin, Liaohe River basin, Haihe River basin, Zhujiang River basin.), the five large lakes(They are Poyanghu Lake area, Dongtinghu Lake area, Taihu Lake area, Hongzehu Lake area, Caohu Lake area), there are about more than 50000 rivers whose basin area is bigger than 100 square-kilometers, there are about more than 1500 rivers whose basin area is bigger than 1000 square-kilometers, and the mean annual total surface runoff flow is more than 3000 billions cubic-meters; the total basin area of the lakes whose area is laeger than 1 square- kilometer is about 74277 square-kilometers, this is almost the area of the Zhejiang province. The lakes are closest in the East Plain and Qinghai-Xizang Plateau Land in China, and they form the two east and west opposite biggest lake cluster; The Chinese coastline begins with Yalu River at the border between China and Korea, end with Beilun River at the border between China and Viet Nam, and the length is more than 18000 kilometers. The huge surface water system covers more than 60 percents area of China [6]. In this thesis we first investigate and analyze of the surface water temperature in December in 17 typical cities, and discover that the surface water sensible heat we can use in the winter is very limited. On the basis of the supplying radius of the surface water, we have investigated in the supplying area and supplying area ratio (SAR) of the surface water heat energy in 102 large and middle cities in China, and we have further investigated the mean heating need index (HNI) and mean cooling need index (CNI), at last we classify

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the 102 cities. The data indicate that the recovering utilization of urban surface water heat energy has a broad and cheerful application prospect in China.

2. THE CHARACTERISTIC OF SURFACE WATER HEAT ENERGY

According to the difference characteristic of surface water heat energy utilization technology, here the surface water is classified into there types as following: rivers that are through city, lakes which are near city, seawater of coastal city. Because the liquidity and heat restorability of rivers are good, it is rather simple and convenient to exploit its energy; For the bad liquidity of lakes, we should avoid stagnant water circulation [6,7]. The most metal material is seriously corroded by seawater [8]. The water quality of urban surface water is much worse than conventional recycled water of air-conditioning, and long-accumulation of large-scale solid contaminants can plug the heat-exchanger or pipe very easily; the small-scale contaminants or solute also can pollute the heat exchange surface very easily [9]. Besides above characteristics, the temperature of surface water is very low in winter and the sensible heat that can be used of it is rather limited.

The author has investigated and surveyed the surface water temperature of 17 typical cities of China in December of 2005The data are in Tab.1.

The data of Tab.1 indicate that the temperature of these natural surface water are between 2~5 in the coldest period in winter. Conventional heat pump equipment is restricted by freezing point; and there is only 0~3℃ temperature difference that can be used, so it's impossible to apply its sensible heat by current technology or it leads to fold increase of surface water demanded quantity; The project investment and pump operating cost may be fold increased too. So it won't have engineering feasibility to only exploit sensible heat from surface water in winter.

In this instance, we need to extract the freezing latent heat of surface cold water. The freezing latent heat of water is about 335kJ（80kcal），moreover than the sensible heat of 1 temperature difference that is only 4.19 kJ（1kcal. If we can exploit a new heat-pump system that can extract the freezing latent heat from cold water, most cities of China, including the coldest northeast, northwest area, will have inexhaustible low order heat source even in winter, because the rivers lakes even whose surfaces are freezing can also used as heat source for heat-pump.

Tab.1 Lowest temperature of surface water ( )

City	Surface waters	temperature
Tianjin	Haihe River, depth: 4.0m	2.0
Beijing	Hucheng river, depth: 1.5m	2.0
Xi'an	Chanhe River, depth: 2.0m	4.2
Shanghai	Huangpujiang River, depth: 3.5m	4.7
Hangzhou	Jinghuangyunhe River, depth: 4.0m	4.8
Nanjing	Qinhuaihe River, depth: 2.0m	4.6
Wuhan	Changjiang River, depth: 4.0m	4.0
Changsha	Xiangjiang River, depth: 3.5m	4.2
Chongqing	Changjiang River, depth: 4.0m	4.3
Zhengzhou	Huanghe River, depth: 3.0m	3.7
Guangzhou	Zhujiang River, depth: 3.0m	5.1
Harbin	Songhuajiang River, depth: 3.5m	1.5
Lanzhou	Huanghe River, depth: 4.0m	2.3
Jinan	Huanghe River, depth: 3.0m	3.1
Shenyang	Hunhe River, depth: 2.0m	1.8
Nanchang	Zhanjiang River, depth: 3.5m	4.2
Nanning	Yongjiang River, depth: 3.0m	4.3

The surface water heat energy in winter must include its freezing latent heat, so we should invent and produce the new freezing latent heat source hest-pump system. It is another characteristic of surface water heat energy utilization.

3. STATISTIC ANALYSIS METHOD

It is supposed that the extension line of the nearby area which is heated by the surface water source heat-pump is parallel to the sideline of the water source, and the vertical distance between the tow line is defined as supplying radius. It's shown in the fig.1. The surface water source supplying radius mainly relates with the scale of the water source and the difficulty of intake project. Generally, the width of the rivers or the area of the lakes can represent the scale or capability of the water source. In this thesis, the sufficiency of the heating or cooling capability of surface water has been considered when each supplying radius have been defined and calculated. To fetch water in downtown area, the distance is longer, the investment is more, the difficulty is higher and the engineering feasibility is smaller. This thesis has used three supplying radius in the process of counting the surface water supplying area. They are separately shown in the tab.2. Actually, for the great rivers or lakes, when the intake water project is simple, the supplying radius can exceed 1500 m [10]. The supplying radius of the surface water is bigger, the supplying urban area is larger, and the application range and potential of the surface water is bigger too.

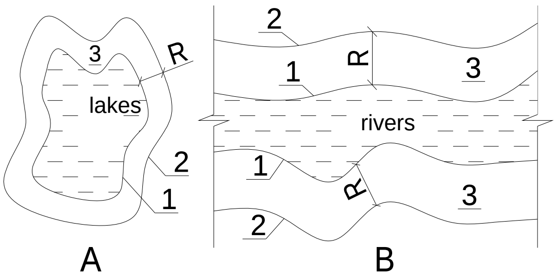

Fig.1 The feeding radius of the surface water

1-the sideline of the water source; 2-the extension line of the supplying area; 3-the supplying urban area; R-the supplying radius

Obeyed the method shown in the fig.1 we can measure and count the surface water supplying urban area of each city. Compared the supplying area with the whole city area, obtained:

$$\zeta = \frac{A_c}{A_t} \qquad (1)$$

Here: ζ -the supplying area ratio;

A_c -the supplying urban area, as area 3 in the Fig.1 (km)^2;

A_t -the whole city area, (km)^2;

Tab.2 The different supplying radius

The surface water source	Supplying radius
The seawater	1500 m
The surface width of river >100m	1500 m
The surface width of river 50~100m	1000 m
The surface width of river 20~50m	500 m
The lake area>5km^2	1000 m
The lake area 1~5km^2	500 m

The mean heating or cooling need index is that the average annual heat or cool load needed by a unit urban area; They are the basic data used to judge the value of surface water heat energy utilization [11]. The approximate calculation formula in this thesis is:

$$q_t = \varphi q_a \frac{t_m - t_n}{t_d - t_n} \qquad (2)$$

Here: q_t -the mean heating or cooling need index, $W/(km)^2$

φ -the urban building plot ratio, that is the ratio of area of structure with the urban ground area, $m^2/(km)^2$;

q_a -the typical load index per unit area, W/m^2;

t_m -the mean outdoor temperature, ;

t_d -the design outdoor temperature, ;

t_n -the indoor design temperature, heating: t_n =20 , air-conditioning: t_n =22 .

Tab.3 Values of the calculation parameters

	Heat load index	Cool load index		Plot ratio φ
Southern China	40 W/m^2	120 W/m^2	Big city	3.0×10^6 m/km^2
Northern China	60 W/m^2	90 W/m^2	Median city	2.5×10^6 m/km^2

For the different cities, the supplying area ratio represents the supplying capability of surface water; the mean heating and cooling need index represent the demand quantity of the city. This thesis used these three parameters to analyze the investigated data and to classify the cities.

4. STATISITC RESULTS ANALYSIS

The author's group has investigated and counted 102 large or median cities in China. The three parameters: supplying area ratio, mean heating need index, mean cooling need index, are calculated and the results are expressed as figure 2, figure 3 and figure 4. These cities are interspersed among almost all the water area of China, so they are the best representation for statistics.

Fig.2 indicates that the supplying area ratios of urban surface water of the 102 cities are in the interval of 5% to 100%. The area ratio is related to the type, the capability or flow of water source and the scale or size of a city. For instance, the 18 cities whose area ratios are above 80% are all median cities and have great rivers flow through. The area ratios of cities in the southland by the Changjiang River, northeast China and coastal region are larger than the ratios of cities in the mid-China and northwest China. The average surface water supplying area ratio of these 102 cities is 42.1% and there are 56 cities exceeding this datum. The application prospect of surface water heat energy in China is very broad and cheerful.

The maximal mean heating need index of the 102 cities is 127.9MW/km^2, the minimum is 53.3MW/km^2, and the difference of them is not very great. The maximal mean cooling need index is 297.8 MW/km^2, the minimum is 14.2 MW/km^2, and their multiple is about 21. The cooling need index is larger than the heating need index of most of these cities. These features can be gained from Fig.3 and Fig.4. The mean heating or cooling need index is influenced by the urban building plot ratio and the outdoor mean air-temperature.

In order to represent the characteristics of surface water heat energy utilization more obviously, the 102 cities are classified by matrix analysis and the result is in Tab.4. Actually there are only seven types of these cities. The taxonomy refers to the supply-demand relationship of surface water heat energy; it also reflects the possibility, capability of surface waters and the load characteristics, design problem of the city buildings. Tab.4 also indicates that the heat load and cool load of most cities in China can not match each other very well. The south cities should choose the equipment capability referring to the cool load and the north cities should refer to the heat load reversely. In the design step, how to assure that the ability of heat-exchanger or heat-carrying ability of pump supplying water can be matched very well in winter and summer, and how to coordinate the optimum relationship among investment, operating cost, reliability, these problems are very important.

5. CONCLUTIONS

It is a new technology in China that heating and air-conditioning by urban surface water source heat-pump. The water temperatures in December winter of the typical 17 cities indicate that there is a very little sensible heat in surface water. Only the freezing latent heat source heat-pump has been invented and produced, could the surface water heat energy utilization has its economic and technical feasibility. The surface water supplying urban area ratio, mean heating and cooling need index of 102 cities in China have been investigated and counted, and about 42.1% waterside buildings can be heating or air-conditioning by the surface water source heat-pump. Referring to the three parameters the 102 cities have been classified into 8 types. The classification tells us that a best match of the heat-exchange ability and heat-carrying ability in winter and summer is very important for an economic and reliable surface water heat-pump system.

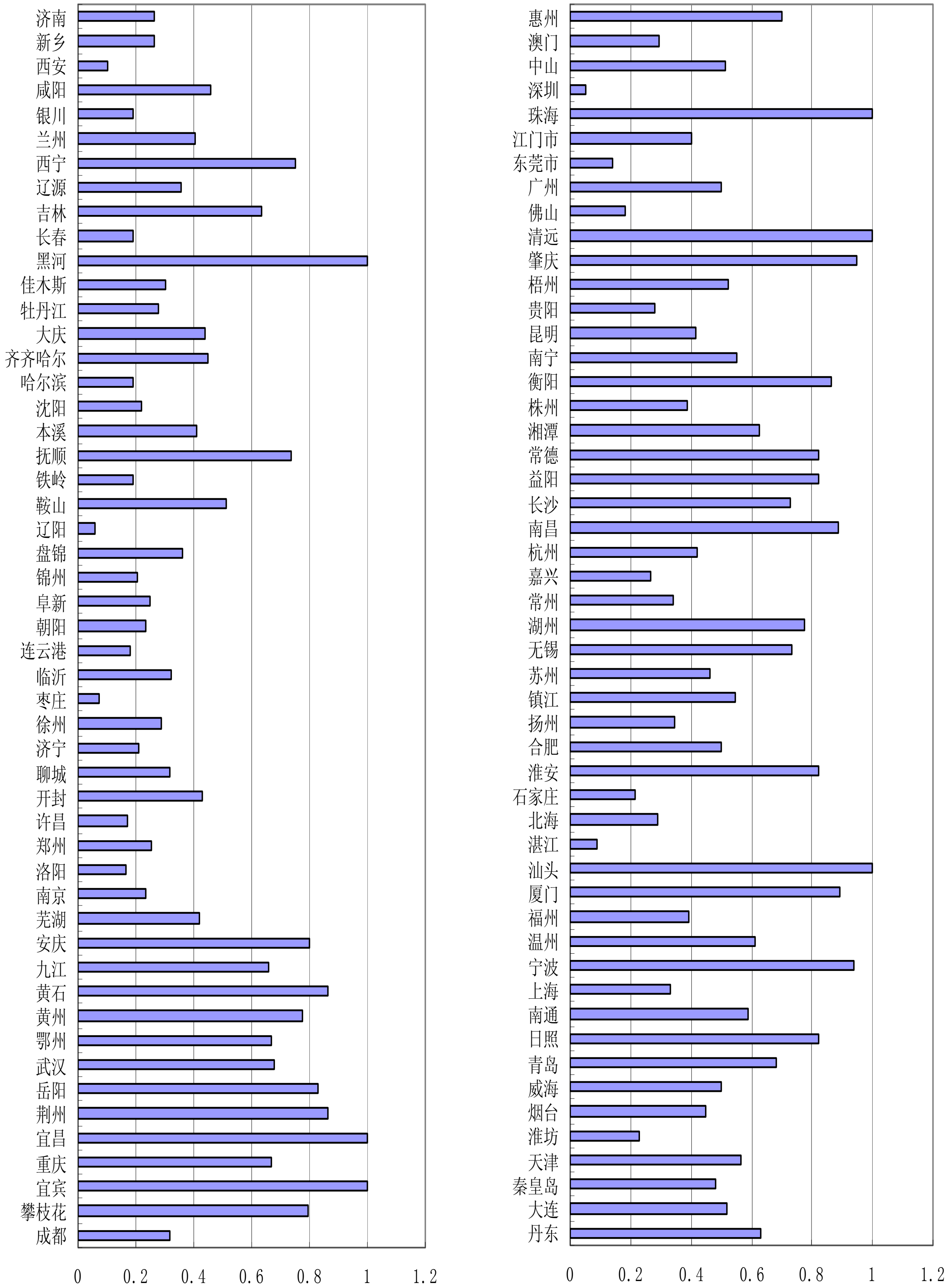

Fig.2 The surface water supplying area ratio of Chinese cities

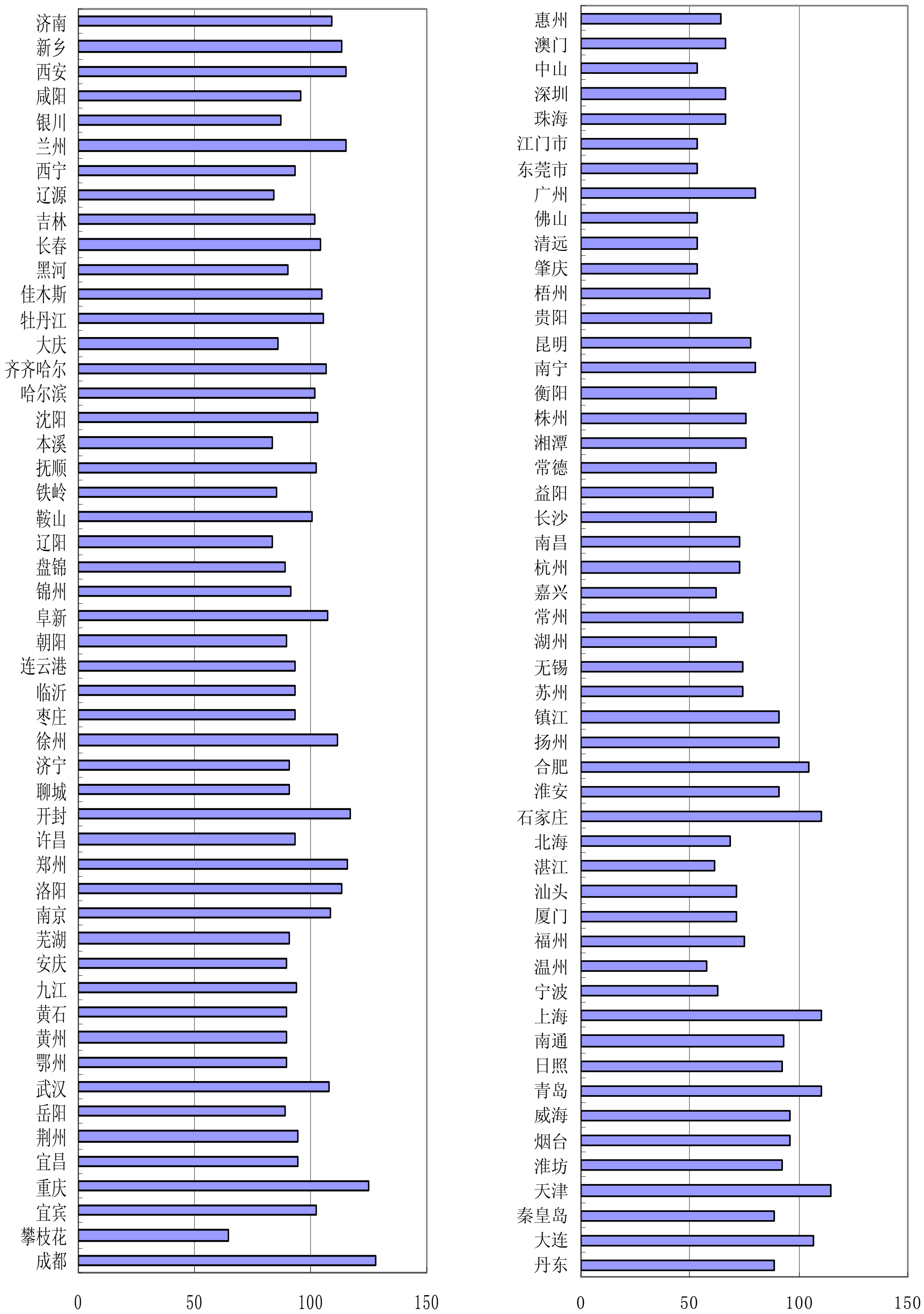

Fig.3 The mean heating need index of Chinese cities（MW/km^2）

Fig.4 The mean cooling need index of Chinese cities（MW/km^2）

Tab.4 The city classification of surface water heat energy utilization

TYPE	CITY NAME	REMARK
Ⅰ	Yibin, Chongqing, Yichang, jingzhou, Yueyang, Wuhan, Ezhou, Huangshi, Huangzhou, Anqing, Wuhu, Nantong, Huai'an, Hefei, Zhenjiang	SAR:large;HNI:large;CNI:large;15cities
Ⅱ	Jiujiang, Kaifeng, Anshan, Fushun, Qiqihar, Heihe, Jilin, Xining, Xianyang, Dandong, Dalian, Qinhuangdao, Tianjin, Yantai, Weihai, Qingdao, Rizhao, Daqing	SAR:large;HNI:large;CNI:small;18cities
Ⅲ	Panzhihua, Ningbo, Wenzhou, Xiamen, Shantou, Suzhou, Wuxi, Huzhou, Hangzhou, Nanchang, Changsha, Yiyang, Changde, Xiangtan, Hengyang, Nanning, Wuzhou, Zhaoqing, Qingyuan, Guangzhou, Zhujiang, Zhongshan, Huizhou	SAR:large;HNI:small;CNI:large;23cities
Ⅳ	——	SAR:large;HNI:small;CNI:small;0 cities
Ⅴ	Nanjing, Shanghai, Yangzhou, Aomen	SAR:small;HNI:large;CNI:large;4cities
Ⅵ	Chengdu, Luoyang, Zhengzhou, Xuchang, Liaocheng, Jining, Xuzhou, Zaozhuang, Linyi, Lianyungang, Chaoyang, Fuxin, Jinzhou, Panjin, Shenyang, Harbin, Mudanjiang, Jiamusi, Changchun, Lanzhou, Yinchuan, Xi'an, Xinxiang, Jinan, Weifang, Shijiazhuang, Liaoyang, Tieling, Benxi, Liaoyuan	SAR:small;HNI:large;CNI:small;30cities
Ⅶ	Fuzhou, Zhanjiang, Beihai, Changzhou, Jiaxing, Zhuzhou, Foshan, Dongguan, Jiangmen, Shenzhen	SAR:small;HNI:small;CNI:large;10cities
Ⅷ	Kunming, Guiyang	SAR:small;HNI:small;CNI:small;2cities

Note: SAR is short for supplying area ratio; HNI is short for mean heating need index; CNI is short for mean cooling need index.

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